Potential for Barn Owl as Rodent Biological Control in Central California Vineyards

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Abstract

The pocket gopher (*Thomomys bottae*) and voles (*Microtus* spp.) cause significant economic damage to vineyards. In response, many growers have taken steps to attract Barn Owls (*Tyto alba*) to their properties to help keep these rodent populations in check. This research project investigated Barn Owl consumption of pocket gophers and voles in Central California vineyards in order to assess the efficiency of this integrated pest management strategy. I collected a total of 715 owl pellets from five vineyard locations in Templeton and Paso Robles, California over an eight-month period during nesting and post-fledging seasons. I identified seven prey species within in the owl pellets, allowing for comparative analysis between the two collection periods. Comparisons of the average number of individuals per species per pellet (AVG) and a paired t-test indicated seasonal diets of Barn Owls are statistically similar. Although there was slight variation in AVG values between seasons, this research did satisfy the expectation that the diets from each vineyard would contain similar percentages of gopher and vole species. *Microtus* was the most highly consumed prey genus and made up the majority of both the spring (AVG = 0.528) and summer diets (AVG = 0.599) with a p-value of 0.77. Seasonal consumption for gophers was statistically similar and *Thomomys bottae* was the second most highly consumed prey species behind *Microtus californicus,* with AVG values of 0.304 (spring) and 0.299 (summer) with a p-value of 0.80. It would be fair to conclude from this snapshot of seasonal consumption that Barn Owls consume important vineyard pests and have the potential to assist in regulating these rodent populations.

Introduction

The viticulture industry produces $61.5 billion in economic value each year for the state of California and therefore serves as a vital part of the state's economy[1]. Vineyard ecosystems, like many other agriculture settings, are enticing to early-successional species such as the Pocket Gopher (*Thomomys bottae)* and California Voles (*Microtus californicus*). These subterranean rodents pose a significant threat to grapevines because of the damage they inflict on developing root systems and irrigation lines[1].

The Barn Owl (*Tyto alba*) is a known predator of *Thomomys* and *Microtus* species[2]. Some vineyard managers use owl boxes as a way to entice Barn Owls to their property in the hopes that they will keep the rodent populations in check, but there are questions regarding the effectiveness of this pest management strategy.

Understanding the life history of the Barn Owl (*Tyto alba*) is essential to understand their potential to impact vineyard pest populations. The Barn Owl is one of the most widespread owls in the world and ranges throughout much of the lower 48 United States[2]. *Tyto alba's* large range can be attributed to their ability to successfully compete in a variety of open habitats ranging from deserts to grasslands, marshes, agricultural lands or metropolitan environments[2]. Another contributing factor to their widespread range is the Barn Owl's versatility in selecting nesting sites. Barn Owls are cavity nesters, seeking out hollows of trees, cliffs, owl boxes and other human made structures such as buildings[2]. These owls do not migrate, staying year round even in the most northern part of their range[2]. Only mildly territorial, Barn Owls defend only a small area in the direct vicinity of their nests during the breeding season[2].

Tyto alba is a medium sized owl; males may range from 32-39 cm in height and 400-560 g in weight, and females, slightly larger, from 33-40 cm and 420-700 g[2]. They can be

distinguished from other owl species by their large, distinctive heart-shaped facial area lacking ear tufts and buff feather coloration[2]. Barn Owls exhibit a monogamous mating strategy and mate for life[2]. A breeding pair of owls will live together at the nesting site for the breeding season and live separately in the non-breeding season[2]. The female will often lay one to two clutches of between five and seven eggs per season[2]. In California, most clutches begin in February and the second clutch is laid 75-80 days after[2]. The female will incubate her eggs for 29-30 days and will rarely leave the nest during which time the male supplies her with food[2]. When the young hatch, they are fed the same diet as their parents, just in smaller pieces[2]. By the time they reach two weeks of age, chicks can swallow larger pieces of food whole[2]. Juvenile birds fledge around 50-60 days after hatching and will breed at one year of age[2]. The average lifespan of these owls is 20.9 months, but they have been known to live up to 34 years in captivity[2].

Barn Owls are effective hunters and prey upon a variety of small mammals that make up a majority of their diet[2]. Like most owls, *Tyto alba* is a nocturnal hunter and is primarily active one hour previous to sunrise and sunset[2]. Several physical attributes allow these owls to be successful hunters: specialized sound dampening feathers allowing for silent flight, eyes that detect movement well in low light, and extensive hearing abilities that can detect prey hiding under vegetation or even under snow[2]. Small mammals such as rodents, shrews, bats and rabbits account for 74-100% of Barn Owl diets; other prey may include birds, reptiles, amphibians or arthropods[2]. Despite their smaller size, a high metabolic rate allows these owls to eat up to one-fourth of their body weight in prey each day with averages of 100-150 g of prey weight[2].

Owls have a unique physiological adaptation that allows for straightforward dietary analysis. Owls generally swallow their prey whole or in large pieces and the indigestible pieces

(hair, bone, exoskeleton, etc.) are regurgitated in the form of a pellet. Pellets prove useful for dietary analysis because they preserve the bones of prey items that can be easily exposed through a simple dissection process. As a result, Barn Owl diets have been studied extensively in the state of California, although there has been a lack of research done on the Central Coast and on owls residing in vineyards[3].

This project hopes to address whether Barn Owls that reside within vineyards consume the important pests *Thomomys bottae* (the pocket gopher) and *Microtus californicus* (California Vole). This question will be answered through a comparison of Barn Owl consumption in five Central California vineyards over an eight-month period consisting of two seasons: winter/spring (December-March) and summer (March-August). This bi-seasonal study will provide a "snapshot" of overall, vineyard-residing, Barn Owl prey selection. I expected the diets from all vineyards and seasons to contain similar percentages of gopher and vole species. My null hypothesis stated that Barn Owl diets would be independent of season; in other words, owl diets will be the same across seasons. My alternative hypothesis stated that Barn Owl diets would vary by season, or, owl diets from different seasons will be statistically different.

Methods

Five vineyards participated in this study (Figure 1), these locations were chosen based on the following qualifications: when combined they would accurately represent the North San Luis Obispo County viticulture area in terms of similar habitat, evenly distributed locations, established owl boxes (Figure 2), and presence of prey species of interest. All locations are in oak woodland and grassland vegetation types, with hot dry summers and cool wet winters. All five vineyards are located in a fifteen-mile radius consisting of Templeton and Paso Robles, California (Figure 1).

Upon visiting each study location, I identified and mapped owl boxes at each vineyard (by marking box locations on previously produced vineyard maps) to ensure all locations would be sampled. In December, areas underneath each nest box were weed wacked and raked clear of weeds and other debris including old pellets to ensure all pellets deposited would be of appropriate time period and easily detected. Pellets were collected at two times, once in March (represents winter/spring season), and a second time in August (represents summer season).

During each collection, all nest boxes sites were visited in order and all pellets in the surrounding area were collected by hand with latex gloves. Samples were segregated into paper bags and placed in cardboard boxes that were labeled with the vineyard name to ensure data from each vineyard would remain separate. Next, pellets were individually wrapped in aluminum foil and autoclaved to ensure samples were sterile and safe for handling (Figure 3). Freshly autoclaved samples were then dissected by hand using a forceps to segregate bone from non-bone material in order to recover prey skulls (Figure 4). Small mammal skulls served as the primary identification material, thus ensuring accurate identification (through cranial characteristics) and to make sure prey items were only counted once. Skulls were identified to genus, and species when applicable, using cranial and cheek teeth morphology under the guidance of the Key-Guide to Mammal Skulls and Lower Jaws[4] and reference specimens. Pellet contents were preserved in re-sealable bags labeled with pellet number, date, identification and quantity of skulls, and vineyard location in indelible marker. I created an Excel spreadsheet for the raw data and the average number of individuals per species per pellet (AVG) was calculated. AVG values for each prey genus from both seasons were compared with the use of a paired t-test.

Results

I collected a total of 715 Barn Owl pellets between the five vineyard locations; 441 from the winter/spring collection and 274 from the summer (Table 1). Table 1 depicts a complete breakdown of pellet numbers from each vineyard location in the winter/spring and summer collection seasons. I identified a total of 1,016 skulls from all pellets collected, 607 from the winter/spring season and 409 from the summer (Table 2). I identified seven different mammalian prey genera across all vineyards: *Thomomys bottae* (Pocket Gopher), *Microtus californicus* (California Vole), *Peromyscus* spp. (Deer Mouse), *Neotoma* spp. (Woodrat), *Dipodomys* spp. (Kangaroo Rat), *Chaetodipus* spp. (Pocket Mouse) and *Mus musculus* (House Mouse). Overall, the top two prey items for both collection seasons were *Microtus californicus* and *Thomomys bottae*. For the winter/spring collection, *Microtus californicus* percentages ranged from 25.8-61.5% of all skulls identified at each vineyard location and *Thomomys bottae* percentages ranged from 13.5-40.9% (Table 2). For the summer collection, *Microtus californicus* percentages ranged from 44.4-64.4% of all skulls identified at each vineyard location and *Thomomys bottae* percentages ranged from 16.4-55.6% (Table 2).

The number of prey items per pellet for all vineyard locations over both seasons ranged from 1-4 items. The average number of prey items per pellet ranged from 1.1-1.8 for all vineyards over both collection seasons, indicating that the majority of the time, Barn Owls were consuming less than two animals per meal (Table 2). To illustrate this observation, the number of species per pellet was also calculated. Over the course of both seasons the number of species per pellet ranged from 1-4 species, while the average ranged from 1.0-1.2 (Table 2). For those instances where more than one prey item was consumed, meals oftentimes consisted of multiple smaller prey taxa such as *Microtus*, *Peromyscus*, *Chaetodipus* or *Mus musculus*;

larger prey items such as *Thomomys bottae*, *Dipodomys* or *Neotoma* were usually consumed individually.

The average number of individuals per species per pellet was found by dividing the total number of skulls found per genus in all vineyard locations by the total number of owl pellets collected at all of the vineyards for that particular season. The averages for each species were compared between both seasons to determine statistical significance to diet similarities of Barn Owls in these vineyards through the use of a paired t-test.

When data from the two collection seasons were compared, I found the prey consumption of Barn Owls to be statistically similar between the winter/spring and summer seasons for all genera except for *Peromyscus spp*. The top prey item was *Microtus californicus* whose consumption was statistically similar between the two seasons: the spring average was 0.528 and 0.599 for summer with a p-value of 0.77 (Tables 3,4,5 and Figure 5). Gophers were the second most consumed prey item; values for *Thomomys bottae* consumption were also statistically similar: the spring average was 0.304 and 0.299 for summer with a p-value of 0.80 (Tables 3,4,5 and Figure 5). *Peromyscus spp.* and *Chaetodipus spp.* followed behind gophers for overall consumption rates. Consumption values for *Peromyscus spp.* were statistically different: the spring average was 0.147 and 0.084 for summer with a p-value of 0.02 (Tables 3,4,5 and Figure 5). Values for *Chaetodipus spp.* were not statistically different: the spring average was 0.122 and 0.117 for summer with a p-value of 1.00 (Tables 3,4,5 and Figure 5). The least commonly consumed taxa consisted of *Dipodomys*, *Neotoma*, and *Mus spp.* Values for *Dipodomys spp*. were not significantly different: the spring average was .009 and 0.0 for summer with a p-value of 0.37 (Tables 3,4,5 and Figure 5). Values for *Neotoma spp.* were not statistically different: the spring average was 0.002 and 0.011 for summer with a p-value of 0.99 (Tables 3,4,5 and Figure 5). And finally, values for *Mus spp.* were not statistically

different: the spring average was 0.005 and 0.015 for summer with a p-value of 0.28 (Tables 3,4,5 and Figure 5).

Discussion

This project compared the diets of Barn Owls from five local vineyards over two different seasons in order to determine if owls residing in vineyards consume the important rodent pest species: the pocket gopher (*Thomomys bottae*) and the vole (*Microtus californicus*). Through comparisons of average number of prey species per pellet data and the use of a paired t-test, seasonal diets of Barn Owls in vineyards were statistically similar throughout all prey categories except for *Peromyscus spp.* (Tables 3,4,5 and Figure 5). Because of these non-significant p-values, this experiment did satisfy the expectation that "the diets from both collection periods would contain a similar abundance of gopher and vole species." In addition to the fact that seasonal consumption of voles was statistically similar, *Microtus californicus* was the most highly consumed prey genus and made up the majority of both the spring (AVG= 0.528) and summer diets (AVG = 0.599) (Tables 3,4,5 and Figure 5). Seasonal consumption for gophers was also statistically similar and *Thomomys bottae* was the second most highly consumed prey species, making up a third of the diet with AVG values of 0.304 (spring) and 0.299 (summer) (Tables 3,4,5 and Figure 5). It would be fair to conclude from this snapshot of seasonal consumption that Barn Owls consume important vineyard pests and have the potential to assist in regulating rodent populations.

The conclusion that *Thomomys spp*. and *Microtus californicus* make up a large proportion of the Barn Owl diet can be supported by the "Summary of California Studies Analyzing the Diet of Barn Owls," written by Chuck Ingels (1995) for the University of California Sustainable Agriculture Research and Education Program[3]. In this paper, the results

of many different dietary studies from 1926-1991 are summarized and an overall percentage of prey species in the Barn Owl diets was calculated[3]. Overall results are as follows: *Microtus californicus* amounted to 31% of total prey items found, *Thomomys spp.* were 18% of the diet while about 33% of the diet were different types of mouse species and 18% consisted of other species[3] (Figure 6). Although the above results are quantified in terms of percentages and my findings consist of AVG data, it is interesting to note that voles, gophers, mice and other animals were consumed in decreasing order as also occurred in our study. A paper written by Thomas Moore, Dirk Van Vuren and Chuck Ingels (1998) also supports my findings[5]. In their analysis of Barn Owls as an integrated pest management strategy for gophers specifically in vineyards and orchards, voles and gophers were found to be the most highly consumed prey genera[5]. In conclusion, most of the Barn Owl dietary studies from California support my findings that *Thomomys spp.* and *Microtus californicus* are the top prey items consumed by Barn Owls.

There are several ways in which this experiment could be improved. First, it would be beneficial to turn this eight-month study into a long-term analysis repeated over the course of multiple years. Through the continuation of this study, one might be able to attain more extensive results of representative rodent consumption of vineyard-feeding Barn Owls. These results would take into account year-to-year prey availability and selection due to cyclic population cycles or climactic events.

Another improvement would be to increase the number of vineyard study areas. While the areas studied in this experiment represent the Paso Robles and Templeton vineyard ecosystems, it would be beneficial to conduct dietary analyses on owls from other locations throughout California. These locations could be in a different region of the state, in a different ecosystem, more urban locations or more rural locations. This information would increase the

understanding of Barn Owl prey selection in different types of vineyard habitats and help vineyard managers to understand the impacts of these birds of prey on their land.

Furthermore, it would be valuable to understand exactly where Barn Owls hunt each night. The main concern with this experiment was the inability to know where the owls hunted. It would be interesting to determine hunting patterns through the use of radio tracking devices that would help us understand hunting patterns. I assumed that owls in vineyards hunt on vineyard property. This assumption is based on two facts: prey is abundant in vineyards, and although home range for owls is highly variable, it has been found that in areas of high prey density, home ranges are smaller[2]. One way for grape-growers to entice owls to hunt on their property would be to place owl boxes in the center of vineyards (rather than along outside property lines). Centered placement of owl boxes ensures owls must fly significantly farther to reach outside prey sources, making them more likely to hunt within the boundaries of the vineyard.

Use of raptor rodent control in vineyards has become increasingly important with the recent sustainable farming movements. In 2002 the California Sustainable Wine Growing Alliance was formed[6]. The main goals of this organization consist of reducing pesticide use and preserving local ecosystems and wildlife habitats[6]. The utilization of Barn Owls in vineyards coincides with the goals of this program. Not only can raptors like Barn Owls reduce the need for pesticides and other costly practices, but they also enhance community dynamics and help foster healthy ecosystems.

In addition to the ecological benefits, owl nest and roost boxes are small in cost compared to the related monetary benefits that accrue to the agricultural industry. According to the Cornell Lab of Ornithology, a Barn Owl typically casts two pellets per day[2]. A simple extrapolation from my data can quantify the impact of a single Barn Owl on a vineyard.

Averaging the overall ratios for both seasons of *Microtus* and *Thomomys* calculated in this study yields 0.56 *Microtus*/pellet and 0.30 *Thomomys*/pellet. Using the calculation in Figure 7, the total impact of a single Barn Owl on a vineyard property can be estimated as 409 *Microtus*/year and 219 *Thomomys*/year (Figure 7). A nesting pair of Barn Owls on a vineyard may consume about 1,256 individuals of the pest species of interest in a single year not including food consumed by young. This calculation is supported by the findings of Colvin (1986) in which he calculated the impact of a nesting pair of Barn Owls with young to be greater than 1,000 rodents/year[7].

Barn Owl boxes can be made for less than $50 with a small amount of labor. Once a box is established on a property it has more than a 40% chance of being occupied within the first six months[5] and once a Barn Owl nests there, it will typically remain in the area year-round[2]. It is possible to have a large number of Barn Owls in a single vineyard location. Because of their low territoriality, many individuals can coexist within a small area and share foraging areas[2]. Even if Barn Owls consume gophers and voles as a majority of their diet, as seen in this study, it still may not be possible for a population of Barn Owls to completely inhibit the negative effects of rodents in vineyards without the addition of some other form of pest control. But, because of the low costs associated with the establishment of a Barn Owl population, the impacts of these owls on vineyard rodents do not have to be extreme in order for vineyard operators to see the benefits outweigh the costs of this integrated pest management strategy.

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Appendix

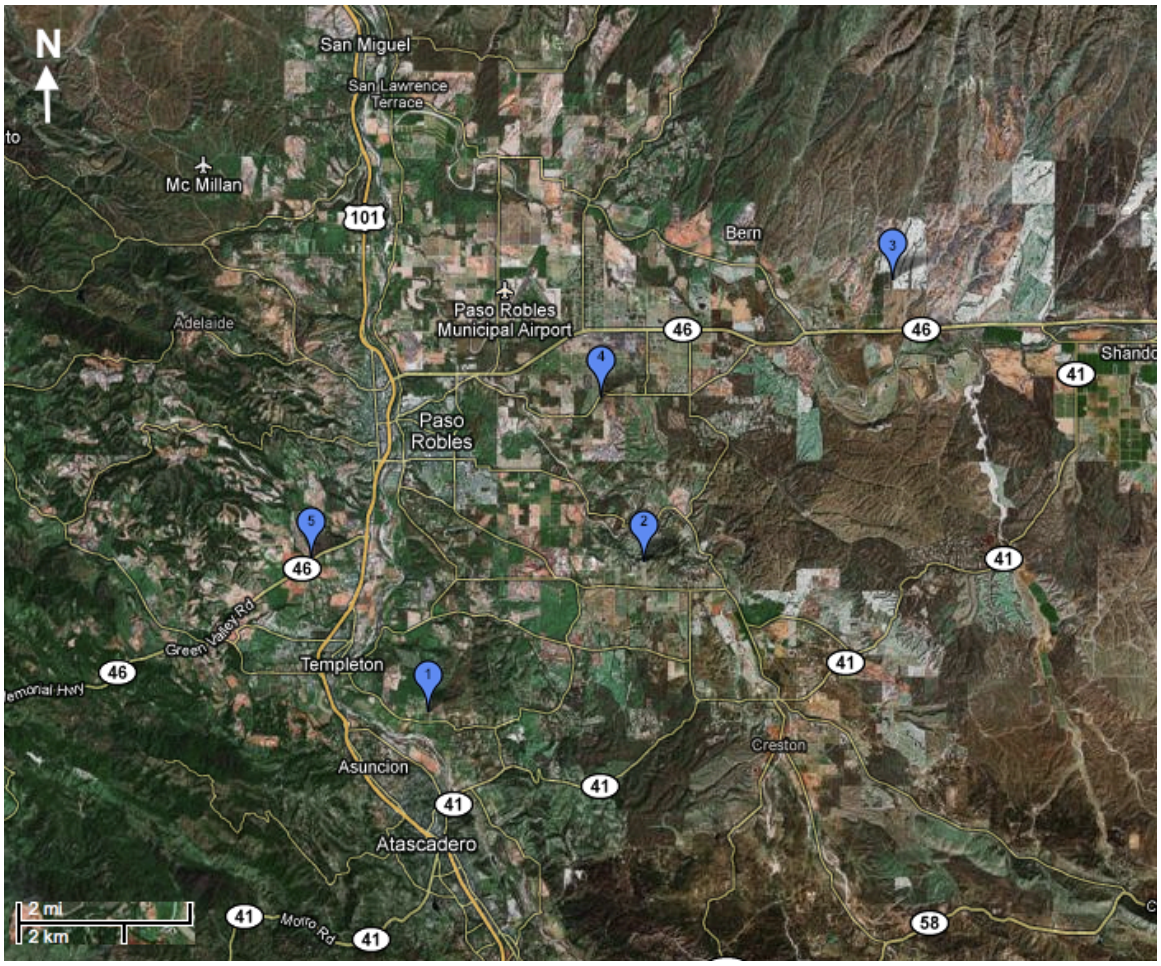

Figure 1 Locations of the five vineyard study sites of the Paso Robles and Templeton, California areas. Numbered locations correspond to the vineyard numbers listed throughout the paper.

Figure 2 *Tyto alba* residing in nest box at location #5.

Figure 3 Owl pellets in wrapping process prior to being autoclaved.

Figure 4 Cleaned *T. bottae* skull.

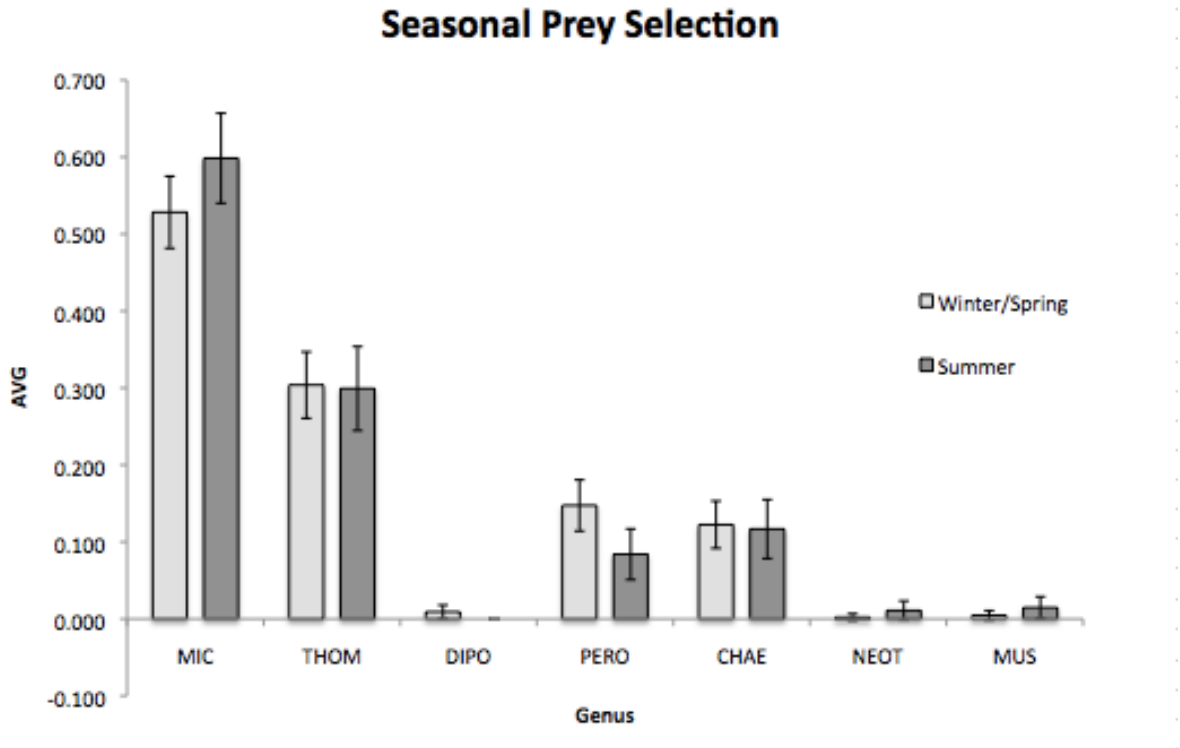

Figure 5 Seasonal prey selection comparisons based on average number of skulls per pellet per species (AVG) for spring and summer collections, error bars indicate 95% confidence intervals. Refer to Table 2 for list of abbreviations.

Table 1. Food Items in Barn Owl Pellets: Summary of California References

Common Name	Scientific Name	Study: Berkeley 1926-27	SF Bay Area 1937	Central Calif. 1945	Davis 1947	Madera Foothills Co. 1947	LA Co. 1960	Placer Co. 1974	Siskiyou Co. 1978	No prey. of	% of Total prey found	Ave. Weight (g)
Calif. meadow vole	Microtus californicus	60	50	6	15	2	10	42	61	2,398	31	54
Pocket gopher	Thomomys bottae	8	21	24	26	37	2	28	0	1.053	18	156
White-footed mice	Peromyscus sp.	14	14	6	12	7	0	25	37	878	14	25
Pocket mice	Perognathus sp.	1	0	36	0	43	0	0	0	609	10	15
Wood rat	Neotoma fuscipes	0	0	3	0	0	65	0	0	90	8	271
House mouse	Mus musculus	3	4	2	38	0	0	0	0	348	6	18
Harvest kangaroo	Reithrodontomys megalotis	8	4	4	3	0	2	0	0	280	3	12
Kangaroo rat	Dipodomys heermanni	0	0	6	0	7	0	0	1	112	2	65
Roof rat	Rattus rattus	0	0	0	1	0	12	1	0	32	2	183
Other species		6	7	13	5	4	9	4	1	388	6	
No. of individual prey found		2480	338	958	749	513	92	660	398	6,188		
Number of pellets found		796	87	NA	280	240	NA	538	143			

Figure 6 "Summary of California Studies Analyzing the Diet of Barn Owls," written by Chuck Ingles for the University of California Sustainable Agriculture Research and Education Program[3].

Extrapolation of Study Data to Estimate Potential Barn Owl Impact on Gophers and Voles

(0.56 *Microtus*/pellet) x (2 pellets/day) x (365 days/year) = 409 *Microtus* per owl/year

(0.30 *Thomomys*/pellet) x (2 pellets/day) x (365 days/year) = 219 *Thomomys* per owl/year

(409 *Microtus* per owl/year + 219 *Thomomys* per owl/year) x (2 owls/ nesting pair) = 1,256 pest species of interest consumed per nesting pair/year (not including young)

Figure 7 Calculation of Barn Owl potential impact on vineyard vole and gopher populations as extrapolated from study data. Prey proportions are calculated from the average ratios seen in Tables 3 and 4.

Vineyard #	Winter/Spring	Summer
1	46	118
2	240	12
3	75	42
4	23	96
5	57	6
Total # pellets	441	274

Table 1 Total pellets collected from each vineyard location for the winter/spring and summer collection; also included are combined vineyard location totals from each collection period.

Winter/Spring		Percentage of each prey species for Winter/Spring season								
Vineyard #	**# Skulls**	**MIC**	**THOM**	**DIPO**	**PERO**	**CHAE**	**NEOT**	**MUS**	**Avg. # species per pellet**	**Avg. # prey items per pellet**
1	68	45.6	36.8	0.0	16.2	0.0	1.5	0.0	1.2	1.5
2	347	56.5	13.5	1.2	15.3	12.7	0.3	0.6	1.1	1.4
3	93	25.8	40.9	0.0	17.2	16.1	0.0	0.0	1.1	1.2
4	26	61.5	19.2	0.0	11.5	7.7	0.0	0.0	1.0	1.2
5	73	60.3	38.4	0.0	1.4	0.0	0.0	0.0	1.1	1.3
Total # skulls	607									
Summer		Percentage of each prey species for Summer season								
Vineyard #	**# Skulls**	**MIC**	**THOM**	**DIPO**	**PERO**	**CHAE**	**NEOT**	**MUS**	**Avg. # species per pellet**	**Avg. # prey items per pellet**
1	18	55.6	33.3	0.0	0.0	5.6	0.0	5.6	1.1	1.5
2	207	60.9	16.4	0.0	9.7	10.1	1.4	1.4	1.2	1.8
3	45	64.4	22.2	0.0	4.4	8.9	0.0	0.0	1.0	1.1
4	130	60.0	27.7	0.0	5.4	6.9	0.0	0.0	1.1	1.3
5	9	44.4	55.6	0.0	0.0	0.0	0.0	0.0	1.0	1.5
Total # skulls	409									

Table 2 Total number of skulls found in pellets collected from each vineyard location for the winter/spring and summer collection. Percentage of prey species for each vineyard location as well as average number of species per pellet and average number of prey items per pellet for each collection period are also shown. MIC stands for *Microtus californicus*, THOM for *Thomomys bottae*, DIPO for *Dipodomys spp.,* PERO for *Peromyscus spp.,* CHAE for *Chaetodipus spp.,* NEOT for *Neotoma spp.* and MUS for *Mus musculus.*

Vineyard #	**MIC**	**THOM**	**DIPO**	**PERO**	**CHAE**	**NEOT**	**MUS**
1	0.57	0.46	0.00	0.11	0.00	0.02	0.00
2	0.58	0.19	0.02	0.18	0.16	0.00	0.01
3	0.27	0.47	0.00	0.19	0.17	0.00	0.00
4	0.57	0.22	0.00	0.13	0.09	0.00	0.00
5	0.60	0.49	0.00	0.02	0.00	0.00	0.00
Overall Ratio	0.528	0.304	0.009	0.147	0.122	0.002	0.005
SE	0.024	0.022	0.005	0.017	0.016	0.002	0.003
t value	1.965						
95% CI	0.047	0.043	0.009	0.033	0.031	0.004	0.006
upper	0.575	0.347	0.018	0.181	0.153	0.007	0.011
lower	0.482	0.261	0.000	0.114	0.092	-0.002	-0.002

Table 3 Average numbers of individuals per species per pellet for each of the seven mammalian prey species identified at each vineyard location (abbreviations in Figure 1) for the winter/spring collection. Refer to Table 2 for list of abbreviations.

Vineyard #	MIC	THOM	DIPO	PERO	CHAE	NEOT	MUS
1	0.58	0.42	0.00	0.00	0.08	0.00	0.08
2	0.63	0.26	0.00	0.13	0.16	0.03	0.03
3	0.60	0.24	0.00	0.05	0.10	0.00	0.00
4	0.58	0.33	0.00	0.06	0.08	0.00	0.00
5	0.33	0.67	0.00	0.00	0.00	0.00	0.00
Overall Ratio	0.599	0.299	0.000	0.084	0.117	0.011	0.015
SE	0.030	0.028	0.000	0.017	0.019	0.006	0.007
t value	1.969						
95% CI	0.058	0.055	0.000	0.033	0.038	0.012	0.014
upper	0.657	0.354	0.000	0.117	0.155	0.023	0.029
lower	0.540	0.245	0.000	0.051	0.079	-0.001	0.000

Table 4 Average numbers of individuals per species per pellet for each of the seven mammalian prey species identified at each vineyard location (abbreviations in Figure 1) for the summer collection. Refer to Table 2 for list of abbreviations.

a) Season: Winter/Spring							
Vineyard #	MIC	THOM	DIPO	PERO	CHAE	NEOT	MUS
1	0.57	0.46	0.00	0.11	0.00	0.02	0.00
2	0.58	0.19	0.02	0.18	0.16	0.00	0.01
3	0.27	0.47	0.00	0.19	0.17	0.00	0.00
4	0.57	0.22	0.00	0.13	0.09	0.00	0.00
5	0.60	0.49	0.00	0.02	0.00	0.00	0.00
b) Season: Summer							
Vineyard #	MIC	THOM	DIPO	PERO	CHAE	NEOT	MUS
1	0.58	0.42	0.00	0.00	0.08	0.00	0.08
2	0.63	0.26	0.00	0.13	0.16	0.03	0.03
3	0.60	0.24	0.00	0.05	0.10	0.00	0.00
4	0.58	0.33	0.00	0.06	0.08	0.00	0.00
5	0.33	0.67	0.00	0.00	0.00	0.00	0.00
Paired-sample T-test, with site as the paired unit (n = 5)							
	MIC	THOM	DIPO	PERO	CHAE	NEOT	MUS
p-value:	0.77	0.80	0.37	0.02	1.00	0.99	0.28

Table 5 Results of paired t-test of comparison between average numbers of individuals per species per pellet in the winter/spring and summer seasons. Refer to Table 2 for list of abbreviations.

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